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DESCRIPTION

POLISHING PAD, PRODUCTION METHOD THEREOF, AND POLISHING METHOD USING THE SAME

TECHNICAL FIELD

The present invention relates to a polishing pad for use in chemical mechanical polishing (CMP), for example, in semiconductor device-manufacturing technologies and for precision polishing in hard disk-manufacturing technologies, a production method thereof, and a polishing method using the polishing pad.

BACKGROUND ART

In the current trend toward increase in packaging density of ultralarge-scale integrated circuits, various microfabrication technologies are now under research and development. The design rule is already in the sub-half micron order. One of the technologies under development for satisfying the strict requirements in microfabrication is CMP (chemical mechanical polishing) technology. The technology is effective in completely flattening the layer to be exposed to light, alleviating the load of exposure technology, and stabilizing the production yield at a high level in the processes for manufacturing semiconductor devices, and the polishing is performed in the following way. The film on the surface of a work material is removed precisely to a predetermined thickness, by pressing the work material to a polishing pad and sliding the polishing pad and the

work material relatively while supplying a CMP polishing slurry in state of slurry between the work material and the polishing pad. Thus, CMP is an indispensable technology, for Example, for flattening of interlayer-insulating and BPSG films, shallow trench isolation, and others.

Form or non-foam organic resin polishing pads have been used as the polishing pads for use in the CMP technology (see Claims and background of the invention in Japanese Patent Application National Publication (Laid-Open) No. 8-511210). Commonly used, for example, is urethane foam resin sheet having concentric or grid-patterned trenches.

There is a problem of damage (polishing scratch) on the polishing plane by abrasive and polishing waste. It is very effective to reduce the rigidity of polishing pad for reduction of polishing scratch when a common polishing pad of a foam or non-foam organic resin is used. However, the decrease in rigidity often results in decrease in polishing speed and deterioration of the dishing of trench area. It was difficult to satisfy these properties at the same time.

Although Al wire has been used in the wiring process, currently, embedded wiring by the dual damascene process, which uses Cu, a metal lower in resistivity, as the wiring metal and a low-dielectric constant material as the interlayer insulating film, is the mainstream process.

In the dual damascene process, it is quite important to select the polishing slurry and the polishing pad adequately. In particular, the metal, which is more chemically reactive and softer than the interlayer insulating film, often causes defects by

polishing scratch and corrosion. On the other hand, dishing occurs more frequently on the material having smaller easiness to deformation, i.e., elastic modulus. However, increase in the elastic modulus of pad generally leads to increase in pad rigidity and consequently to defects such as polishing scratch.

In addition, recent application of a low-dielectric constant material to the interlayer insulating film is accompanied by deterioration in the mechanical properties of insulation layer and the adhesion with metal and is a factor causing defects during polishing, and thus, there is a need for a polishing system having lower mechanical load demands during polishing.

Further, it is necessary to control the polishing amount adequately during CMP polishing, in the shallow trench isolation step metal wiring polishing step in dual damascene process, and interlayer insulating film-polishing step. Examples of the methods include strict control of the polishing period, detection of the variation in torque of the motor driving the polishing machine due to the change in the friction between pad and wafer during polishing, and measurement of the electrostatic capacity of work material. Recently however, polishing machines equipped to optically detect changes in the wafer surface state during polishing are increasingly available, and technology for controlling the wafer polishing state by irradiating a laser beam or infrared ray from a polishing machine via a polishing pad onto the polishing plane of a wafer and detecting the reflected beam once again via the polishing pad by a sensor in the polishing machine is becoming predominantly popular. The optical method is useful especially in the shallow trench isolation step and the dual

damascene method, because a barrier film is exposed on the wafer surface at the end of polishing and a high reflectance change can be obtained if a light with a suitable wavelength is used for detection. In the step of polishing an insulation film having no barrier film, it is possible to detect the polishing amount from the interference between the reflected beam from wafer surface and the reflected beam from the silicon layer beneath insulation film. A polishing pad of a polyurethane foam resin plate having a transparent window allowing transmission of light formed in part thereof is used as a typical example of the polishing pad using such an optical method. Also proposed are a method for making a polishing pad of a non-foam resin, such as polyurethane, polycarbonate, nylon, acrylic polymer or polyester, transmit light (e.g., U.S. Patent No. 5605760). However, these polishing pads have problems demanding reduction of polishing scratch during CMP polishing and preservation of polishing speed while optical detection of end point, and in particular in the damascene, as described above it is important to reduce generation of the defects caused by polishing scratch and corrosion.

DISCLOSURE OF THE INVENTION

The present invention is completed after intensive studies on the structure of polishing pads to solve the problems above.

The present invention provides a polishing pad that allows efficient flattening and formation of metal wiring in the CMP technology used in flattening of interlayer insulating film, BPSG film, insulation film for shallow trench isolation and the like, and formation of metal wiring in the semiconductor

device-manufacturing process, and suppression of the scratches on polishing plane and the defects of insulation layer, a production method thereof, and a polishing method using the polishing pad. It also provides a polishing pad that has a light transmission suitable for use in the polishing step of irradiating light via a polishing pad onto the surface of a work material such as semiconductor wafer, detecting the change in reflectance, and controlling the polishing end point and suppresses generation of polishing scratch on the work material, and a polishing method for polishing by using the polishing pad.

The present invention relates to (1) a polishing pad comprising a fiber including organic fiber and a matrix resin holding the fiber, wherein at least the organic fiber is exposed on the work material-side surface thereof.

The present invention also relates to (2) a polishing pad comprising a fiber including organic fiber and a matrix resin holding the fiber, wherein at least the organic fiber is exposed on the work material-side surface after dressing treatment.

The present invention relates to (3) the polishing pad described in (1) or (2), wherein the matrix resin contains at least one thermoplastic resin.

The present invention relates to (4) the polishing pad described in any one of (1) to (3), wherein the matrix resin is a semicrystalline thermoplastic resin.

The present invention relates to (5) the polishing pad described in any one of (1) to (4), wherein an elastomer is dispersed in the matrix resin.

The present invention relates to (6) the polishing pad

described in (5), wherein the elastomer has a glass transition point of 0°C or less.

The present invention relates to (7) the polishing pad described in any one of (1) to (6), wherein the fiber is an aromatic polyamide.

The present invention relates to (8) the polishing pad described in any one of (1) to (7), wherein the polishing pad contains an inorganic fiber in an amount of 1 to 50 wt %.

The present invention relates to (9) the polishing pad described in any one of (1) to (8), wherein the organic fiber has a diameter of 1 mm or less.

The present invention relates to (10) the polishing pad described in any one of (1) to (9), wherein the organic fiber has a length of 1 cm or less.

The present invention relates to (11) the polishing pad described in any one of (1) to (10), wherein polishing particles are held by the organic fiber exposed on the work material-side surface.

The present invention relates to (12) the polishing pad described in any one of (1) to (11), wherein the maximum length of the exposed organic fiber is 0.1 mm or less.

The present invention relates to (13) the polishing pad described in (12), wherein the exposed organic fiber is a polyester.

The present invention relates to (14) the polishing pad described in (12) or (13), wherein a chopped polyester fiber is dispersed in the matrix resin.

The present invention relates to (15) the polishing pad described in (12) or (13), wherein polyester nonwoven fabrics are

laminated in the matrix resin.

The present invention relates to (16) the polishing pad described in any one of (1), (2) to (4), (7), and (9) to (11) that is useful for optical detection of the polishing end point during polishing of the work material surface, wherein the polishing pad contains a substantially non-foam matrix resin containing an organic fiber in an amount of 1 to 20 wt %, has the functions of transporting and retaining polishing slurry particles, and allows transmission of a light having a wavelength in the range of 190 to 3,500 nm.

The present invention relates to (17) the polishing pad described in any one of (1), (2) to (4), (7), and (9) to (11) that which is useful for optical detection of the polishing end point during polishing of the work material surface, wherein the polishing pad contains a region transmitting a light having a wavelength in the range of 190 to 3,500 nm that is made of a substantially non-foam matrix resin containing an organic fiber in an amount of 1 to 20 wt % and has the functions of transporting and retaining polishing slurry particles.

The present invention relates to (18) the polishing pad described in (16) or (17), wherein the organic fiber is an aramide fiber.

The present invention relates to (19) a method for producing a polishing pad for use as attached to a polishing table for flattening a work material's polishing plane comprising a step of obtaining a mixture of a fiber including organic fiber and a matrix composition containing a thermoplastic resin by blending, a step of pelletizing or tabletizing the mixture, and a step of

molding the pellet or tablet into a plate or a sheet shape by extrusion or injection molding.

The present invention relates to (20) a method for producing a polishing pad for use as attached to a polishing table for flattening a work material's polishing plane comprising a step of impregnating a fibrous base material containing organic fiber with a matrix resin composition to form a fibrous resin-impregnated sheet-shaped base material, and a step of laminating fibrous sheet-shaped base materials including the fibrous resin-impregnated sheet-shaped base material and molding the laminate with heating and pressure.

The present invention relates to (21) the method for producing a polishing pad described in (19) or (20), further including a step of exposing the fiber on the surface.

The present invention relates to (22) a polishing method for polishing a work material's polishing plane, comprising polishing the work material by pressing the polishing plane of the work material to the organic fiber-exposed face of the polishing pad described in any one of (1) to (18) and sliding the work material and the pad relatively while supplying a polishing slurry between the work material's polishing plane and the polishing pad.

The present invention relates to (23) the polishing method for polishing a work material's polishing plane described in (22), wherein the work material's polishing plane is a laminate of a conductor layer as well as a copper layer formed on an insulation layer having a dielectric constant of 2.7 or less on which wiring and trenches are formed.

The present invention relates to (24) a polishing method

for detecting the polishing end point optically by using the polishing pad described in any one of (16) to (18).

The surface-exposed organic fiber relaxes the stress between the abrasive and the foreign materials in polishing slurry and the work material during polishing to prevent generation of scratches on the surface of the work material. In addition, although foam holes and small and large trenches on the surface in the conventional polishing pads made only of a common resin are responsible for transportation and retention of the abrasive in the polishing slurry, in the polishing pad according to the present invention the surface-exposed organic fiber is responsible for the transportation and retention of the abrasive in the polishing slurry and plays a role of improving polishing speed and uniformity in flatness.

BEST MODE FOR CARRYING OUT THE INVENTION

The polishing pad according to the present invention has a structure consisting of a fiber including organic fiber and a matrix resin holding the fiber. The organic fiber may be included as all or part of the fiber, and the fiber may contain an inorganic fiber such as glass fiber in addition to the primary organic fiber.

The structure of the pad is not particularly limited, if the pad has at least the organic fiber exposed on the work material-side surface of the pad. In the present invention, the phrase "the organic fiber is exposed" includes the case of the work material-side surface after dressing treatment, i.e., means that at least organic fiber is exposed at least during use on.

Typical examples of the structure of polishing pad include

a structure wherein a chopped fiber is dispersed in a matrix resin, a structure wherein woven or nonwoven fabrics of a fiber are laminated in a matrix resin, and the like.

Any one of common thermosetting and thermoplastic resins may be used without limitation as the matrix resin holding a fiber in the polishing pad according to the present invention. Preferable are resins relatively higher in elastic modulus, for example, those having a room-temperature elastic modulus of 0.1 GPa or more, more preferably 0.5 GPa or more after curing. A resin with a smaller elastic modulus may give a polishing plane poorer in flatness.

Examples of the thermosetting resins favorably used include epoxy resins such as bisphenol A epoxy resins, cresol novolak epoxy resin, unsaturated polyester resins, acrylic resins, polyurethane resins, and the like. These resins may be used alone or in combination of two or more. When an epoxy resin is used as the thermosetting resin, it is usually blended with a curing agent, a curing accelerator, and the like. Examples of the curing agents include dicyandiamide, organic acids, organic acid anhydrides, polyamine, and the like. While examples of the curing accelerators include 2-ethyl-4-methylimidazole and the like.

Examples of the thermoplastic resins include polycarbonate, polymethyl methacrylate, AS (acrylonitrile-styrene copolymer), ABS (acrylonitrile-butadiene rubber-styrene copolymer), polyethylene, polypropylene, polybutene, 4-methyl-pentene-1, ethylene-propylene copolymer, ethylene-vinyl acetate copolymer, polyester, polyamide, polyamide-imide, polyacetal, and the like. These resins may be used alone or in combination of two or more.

In particular, it is possible to obtain a polishing pad superior in abrasion resistivity and higher in durability by using a semicrystalline thermoplastic polymer resin as the matrix resin.

The first embodiment of the polishing pad according to the present invention is a polishing pad containing at least one thermoplastic resin in the matrix resin. The matrix resin is not particularly limited, if it contains at least one thermoplastic resin, and a matrix resin containing thermoplastic resin as the principal component is preferable.

The second embodiment of the polishing pad according to the present invention is a polishing pad in which the maximum length of the organic fiber exposed out of the work material-side surface is 0.1 mm or less. The maximum length of the exposed organic fiber is the maximum value among the lengths of the exposed region of the fibers that are substantially embedded in the polishing pad surface. It is practically possible to determine the maximum length by observing five or more points on the pad surface, for example, by using a SEM (scanning electron microscope).

The third embodiment of the polishing pad according to the present invention is a polishing pad useful for optical detection of the polishing end point during polishing of the work material surface, part or all of which is substantially made of a non-foam matrix resin containing organic fiber in an amount of 1 to 20 wt % that transmits a light having a wavelength in the range of 190 to 3,500 nm, and which has functions of transporting and holding polishing slurry particles.

In particular in the first embodiment, an additive, such as crosslinked or uncrosslinked elastomer, crosslinked

polystyrene or crosslinked polymethyl methacrylate, may be dispersed together with the thermoplastic resin in the matrix resin. Addition of a thermoplastic elastomer and a low-crosslinked elastomer is more preferable. The elastomer is not particularly limited, if it has a glass transition point of not higher than room temperature, and an elastomer having a glass transition point of 0°C or lower is more preferable. Examples of thereof include olefinic elastomers, styrene elastomers, urethane elastomers, ester elastomers, and elastomers of alkenyl aromatic compound-conjugated diene copolymer or polyolefin copolymer, and the like. Increase in the amount of the elastomer added results in a persistent resinhigher in impact resistance and increase in the friction force between pad surface and metal.

A wide range of materials that can be processed into the fibrous form including aramide, polyester, polyimide, and the like may be used as the organic fibers in the polishing pad according to the present invention. Two or more materials selected from them may be used in combination.

From the points of the durability of pad and the retention of abrasive particles by the fiber, use of an aramide fiber, i.e., an aromatic polyamide fiber, entirely or partially as the principal component is preferable, and use of an aramide fiber alone is more preferable. It is because the aramide fiber, which is higher in tensile strength than other common organic fibers and thus remains on the surface in a greater amount when the surface of the polishing pad according to the present invention is roughened mechanically for exposure of the fiber, is effective for retention of abrasive particles. In addition, use of it also improves the durability

of polishing pad and lengthens its lifetime during use. Use of an aramide fiber is particularly preferable in the first and third embodiments.

There are two kinds of aramide fibers, para-and meta-aramide fibers, but the para-aramide fiber is more preferable, as it is higher in dynamic strength and lower in hygroscopicity than the meta-aramide fiber. A commercially available product, poly-p-phenylene terephthalamide fiber and poly-p-phenylene diphenylether terephthalamide fiber, may be used as the para-aramide fiber.

It is also preferable to use polyester as the principal component of the organic fiber for adjustment of the maximum exposure length and the surface roughness. It is because use of a polyester fiber allows reduction in the maximum exposure length, as the polyester fiber has a smaller shearing strength than hard fibers when the polishing pad is processed for exposure of the fiber out of the polishing pad. Use of it is particularly preferable for the polishing pad in the second embodiment. Alternatively, when other hard fiber such as aramide fiber or polyimide fiber is used, the maximum exposure length is controlled by reduction in the diameter of the whetstone particles used. The surface roughness of the pad depends on the diameter of the whetstone particles then, and thus, the diameter of the particles influences on the irregularity of the pad surface and thus on polishing speed. On the contrary, when a polyester fiber is used, the exposure length hardly varies, no matter which whetstone is used among those different in particle diameter. Thus, it becomes possible to adjust the surface roughness of the pad itself freely while

maintaining the fiber length to a constant value.

The hard fibers described above may be used as mixed with a polyester fiber. The content of the polyester fiber then is preferably 40 to 100 wt %, more preferably 70 to 100 wt %, and still more preferably 80 to 100 wt %. Increase in the content of polyester fiber may lead to decrease in the thickness of the fiber-exposed layer, while increase in the content of hard fiber may lead to increase in the thickness of the layer and deterioration in the flatness of polishing plane.

The diameter of the organic fiber is preferably 1 mm or less, more preferably 200 μm or less, still more preferably 1 to 200 μm, and still more preferably 5 to 150 μm. An excessively large diameter may lead to an excessively high mechanical strength, occasionally causing polishing scratch and inadequate dressing. Alternatively, an excessively smaller diameter may lead to deterioration in handling efficiency and in pad durability because of insufficiency in strength.

The length of the fiber length is not particularly limited, but in the case of a polishing pad containing chopped fiber dispersed in a resin, the length is preferably 10 mm or less, more preferably 5 mm or less, and still more preferably, 0.1 to 3 mm. An excessively shorter length may lead to lack of maintaining effectively the exposed fibers on the pad when the pad surface is roughened mechanically, while an excessively longer length may make molding of a mixture of a resin and the fiber difficult because of the increase in viscosity of the mixture. Both of the short fibers chopped to a specific length and a mixture of several fibers different in length may be used.

In addition, the fiber surface may be previously roughened mechanically or chemically or modified, for example, with a coupling agent for improvement in compatibility with the resin. Bundles of chopped short fibers adhered to each other with an extremely small amount of resin may be used for convenience in handling. However, the resin for adhesion may be added in an amount that the short fibers can be dispersed in the matrix resin by the heat or the shearing force applied during agitation with the matrix resin.

As for a polishing pad of woven or nonwoven fabric laminate, if a non-woven fabric is used, a sheet produced by binding fibers of 1 mm or more in length similar to above by the adhesive force of the fiber itself or with an adhesive may be used as the non-woven fabric. The adhesive is, for example, an epoxy resin adhesive such as water-soluble epoxy resin binder, or the like. When an adhesive is used, the amount is not particularly limited, but is preferably 3 to 20 parts, more preferably 5 to 15 parts by weight, with respect to 100 parts by weight of the fiber. Alternatively when a woven fabric of long fiber is used, the weaving pattern of the fabric is not particularly limited. A polishing pad containing a laminate of such fabrics is particularly favorable as the polishing pad in the second embodiment of the present invention.

The unit weight of the nonwoven and woven fabrics above is preferably 36 to 100 g/m^2 and more preferably 55 to 72 g/m^2.

The content of the organic fiber is not particularly limited, but, is preferably 1 to 50 wt % in the entire pad, more preferably 1 to 20 wt %, and still more preferably 5 to 20 wt % when a chopped

fiber is used entirely in the pad. Decrease in the fiber amount may tend to result in significant increase in the number of polishing scratches on the polishing plane, while increase thereof in deterioration in molding efficiency. On the other hand, in the case of a woven or nonwoven fabric, the content is preferably 50 wt % or more and more preferably 60 to 80 wt %.

In the third embodiment particularly, the content of organic fiber in the optically transparent region should be in the range that does not inhibit light transmittance and allows detection of the polishing state of the wafer. Thus, the content of organic fiber is preferably 1 to 20 wt % and more preferably 2 to 10 wt % in the entire polishing pad. A smaller fiber content may lead to increase in the number of the polishing scratches on polishing plane, while a greater content to deterioration in molding efficiency.

The polishing pad may be produced, for example, by a method for dispersing a fiber in a matrix resin composition and molding the resulting mixture, or a method for preparing a prepreg by impregnating a woven or non-woven fabric containing fiber with a varnish of resin and laminating such prepregs, but is not limited thereto.

Hereinafter, methods of producing the polishing pad according to the present invention will be described.

The first production method includes a step of obtaining a mixture of a fiber including organic fiber and a matrix resin composition by blending, a step of pelletizing or tabletizing the mixture, and a step of molding the pellet or tablet into a plate or sheet shape by extrusion or injection molding. The second

production method include a step of impregnating a fibrous base material containing organic fiber with a matrix resin composition to form a fibrous resin-impregnated sheet-shaped base material, and a step of laminating fibrous sheet-shaped base materials including the fibrous resin-impregnated sheet-shaped base material and molding the laminate with heating and pressure. The fibrous base material preferably contains a polyester fiber primarily.

The matrix resin composition for production of the polishing pad according to the present invention may be prepared and mixed with a fiber in and any one of known methods without limitation particularly.

In the first production method, if a chopped fiber is to be dispersed in a matrix resin composition as it is, matrix-forming resin compositions are blended (dry blended) uniformly, for example, in a Henschel Mixer, super mixer, tumble mixer, ribbon blender, or the like, and melt kneaded, for example, in a single screw extruder, biaxial extruder, Banbury mixer, or the like. Then, the fiber is added and melt-blended. The mixture is then cooled, and tabletized or pelletized. The composition should be dehydrated thoroughly by drying, if water is used for cooling.

It is possible to form a sheet- or plate-shaped molding, by extruding once again the tablet or pellet obtained from an extruding molding machine through a die and rolling the extruded resin with a roll. Alternatively in another production method, the sheet- or plate-shaped molding is prepared, by injection-molding in a metal mold, instead of the extrusion molding above.

When the matrix resin composition is a liquid thermosetting resin composition, it is possible to mold the resin composition, by dispersing a predetermined amount of chopped fiber in the liquid thermosetting resin composition, pouring the dispersion in a mold or the like, removing air bubbles therein under reduced pressure, and then heat curing the dispersion. The molding may also be produced by pouring the dispersion into a mold while heating under pressure.

The second production method may also be performed by any one of known methods, and is particularly suitable for production of the polishing pad in the second embodiment. For example, if a woven or nonwoven fabric is used as the fibrous base material, the fibrous resin-impregnated sheet-shaped base materials, or alternatively a fibrous resin-impregnated sheet-shaped base material and a fibrous non-resin-impregnated sheet-shaped base material (woven or nonwoven fabric), are prepared. It is possible to obtain a molding by integrating these base materials by molding with heating and pressure. It is also preferable then to make some organic fibers exposed on the surface by placing a fibrous non-resin-impregnated sheet-shaped base material at least on one surface.

The fibrous resin-impregnated sheet-shaped base material is produced by impregnating a fibrous non-resin-impregnated sheet-shaped base material with a resin composition and normally called a prepreg. The method for producing the prepreg is not particularly limited, and the prepreg can be produced by preparing a varnish by dissolving matrix resin composition components in an organic solvent, impregnating a fibrous non-resin-impregnated

sheet-shaped base material with the varnish, and heating and drying the resulting base material. The solvent for use is not particularly limited, if it dissolves the resin composition uniformly. Examples thereof include ketones such as methylethylketone, methylisobutylketone, and acetone; lower alcohols such as ethyl alcohol, propyl alcohol, and isopropyl alcohol; amides such as dimethylformamide and formamide; and the like, and these solvents may be used in combination. The content of fiber in the fibrous resin-impregnated sheet-shaped base material is preferably 60 to 140 parts by weight, more preferably 90 to 120 parts, with respect to 100 parts by weight of the total of resin composition and adhesive.

The rate of the fibrous non-resin-impregnated sheet-shaped base material in polishing pad is decided properly, taking into consideration the fiber content in the polishing pad, in particular the content of the organic fiber on the surface to be pressed to the work material. By the method, it is not necessary to change the resin content during production of the prepreg, for alteration of the fiber content in the polishing pad, but the fiber content can be modified only by changing the rate of the fibrous non-resin-impregnated sheet-shaped base material used.

In molding with heating and pressure, the heating temperature is generally 150 to 200°C, and the pressure is 50 to 500 kPa. These parameters may be changed suitably according to the kind and the content of the thermosetting resin used.

The final polishing pad product is obtained by processing the molding as needed into a shape suitable for the specific polishing table shape of the polishing machine. For example, a

final polishing pad product can be produced by cutting the sheet-shaped molding into a circular form.

The thickness of the entire polishing pad is preferably 0.1 to 5 mm and more preferably 0.5 to 2 mm. Trenches for transporting polishing slurry and polishing waste may be formed on the polishing plane of the pad in the concentric or grid pattern, for example, by using an NC lathe.

For obtaining the polishing pad according to the present invention having at least organic fiber exposed on the work material-side surface, the fiber is exposed by treating the work material-side surface of the pad as needed. One of the methods for exposing the fiber is dressing treatment, a method for exposing the fiber by scraping off the surface resin of the pad by using a whetstone such as diamond particles. Other material such as wire brush, metal scraper, resin brush, or glass or ceramic plate may be used instead of the whetstone.

The condition of using these materials should be decided carefully, for adjustment of the exposure length of fiber. The maximum exposure fiber length depends largely on the rigidity of fiber, but use of a polyester fiber in the pad allows easy adjustment thereof to a smaller length.

The maximum length of the exposed region of the organic fiber exposed on surface is practically 1 mm or less, more preferably 200 μm or less, still more preferably 1 to 200 μm, and still more preferably 10 to 150 μm. Shorter exposed organic fiber may be less effective in holding polishing slurry, leading to decrease in polishing speed, while longer organic fiber may give an adverse influence on the flatness of the polishing place.

In particular in the polishing pad in the second embodiment of the present invention, the maximum length of the exposed organic fiber is 0.1 mm or less. Although satisfactory if it is 0.1 mm or less, the maximum exposure length is preferably 1 to 50 μm and more preferably 1 to 25 μm. Increase in the maximum exposure length leads to deterioration in flatness, while decrease leads to deterioration in polishing speed.

The organic fiber exposed on the work material-side surface retains the polishing particles (abrasive) efficiency contained in the polishing slurry described below during polishing.

Hereinafter, the polishing pad in the third embodiment of the present invention will be described. The polishing pad allows optical detection of the polishing amount of the work material, controls the end point, and suppresses generation of the polishing scratches during polishing while preserving high polishing speed and uniformity. Such a configuration can be obtained by modifying the structure of polishing pad, resin composition, filling material, or the like.

In the structure of the polishing pad, the polishing pad is made of a material allowing transmission of a light having a wavelength in the range of 190 to 3,500 nm, or part of the polishing pad is made of the optically transparent material. In the latter case, for example, a small piece of the optically transparent polishing pad is inserted as a transparent window in part of another polishing pad that does not transmit light sufficiently.

Because the polishing pad or part thereof allows transmission of a light having a wavelength in the range of 190 to 3,500 nm, it is possible to manage the polishing end point by irradiating

the light via the polishing pad on a polishing place of a work material and measuring the change in reflectance. In the present invention, the term, the polishing pad or part thereof allowing transmission of a light having a wavelength in the range of 190 to 3,500 nm, means that the polishing pad or part thereof has a transmittance of the light at the wavelength at 10 to 100% before the organic fiber is exposed. The transmittance is preferably 30 to 100%.

Resins relatively higher in elastic modulus are favorable as the matrix resin for use as the optically transparent material, and the resins described above may be used without restriction. In particular, use of a semicrystalline thermoplastic polymer resin is effective in producing a polishing pad superior in abrasion resistivity and higher in durability. The resin is preferably in the form substantially free from foam holes. It is because a resin containing foam holes inhibits light transmission and detection of polishing state of a wafer. An aramide fiber is preferably selected as the single or primary component of the organic fiber.

The polishing pad is produced in a similar manner to the production method described above, and specifically, each molding is cut into a polishing pad in the predetermined shape (e.g., circular shape) corresponding to the polishing table shape of polishing machine, or the molding is processed into a small piece and inserted as an optically transparent window into a hole in other polishing pad lower in light transmission, to give a polishing pad allowing optical detection. In the latter case, it is preferable to prepare a polishing pad lower in light transmission

having a hole for insertion of the window also with a resin plate or the like containing an organic fiber, to enhance the advantageous effects of the present invention, but the fiber content is not particularly limited. The window inserted should be in contact with the work material on the pad surface during polishing. It is because, if the window and the work material are significantly separated from each other, the polishing slurry may flow into the space and inhibit optical detection by scattering the transmitted light. The shape of the window is not particularly limited, but the size thereof should be large enough to ensure an optical path allowing proper operation of the photoirradiator/detector sensor system placed in the polishing machine for optical detection, and the window preferably has an area of approximately 0.1 to 10% with respect to the entire of the polishing pad surface.

Hereinafter, the polishing method by using the polishing pad according to the present invention will be described. The polishing method according to the present invention is a method for polishing a work material's polishing plane by pressing the polishing plane of the work material to the organic fiber-exposed face of any one of the polishing pads according to the present invention described above and sliding the pad and the work material relatively while supplying a polishing slurry between the work material's polishing plane and the polishing pad.

Examples of the work materials include the substrate carrying a silicon oxide film formed, for example, by the TEOS-plasma CVD method after a device pattern is formed thereon with a silicon nitride film and the Si exposed area is etched in the shallow trench isolation step, and the substrate having an interlayer insulating

film having viaholes and wiring trenches formed by dry etching, a barrier conductive film that cover the openings and the internal wall completely formed thereon and additionally a Cu film formed thereon in the state without any opening in the damascene method.

The CMP polishing slurry for use in the polishing method according to the present invention is not specified here, but an example thereof for insulation films is a polishing slurry prepared by dispersing a composition consisting of cerium oxide (ceria) or silicon oxide (silica) particles and a dispersant in a dispersion medium such as water and adding additives additionally. The polishing slurry for metal layers such as of Cu is, for example, a polishing slurry prepared by dispersing abrasive such as silica, alumina, ceria, titania, zirconia, or germania, additives, and an anticorrosive in water and adding peroxides additionally. Colloidal silica or alumina particles are particularly favorable as the abrasive. The content of the abrasive particles is preferably 0.1 to 20 wt %. The abrasive particles may be prepared in any way, but the average diameter is preferably 0.01 to 1.0 μm. The abrasive particles having an average diameter of less than 0.01 μm leads to decrease in polishing speed, while that of more than 1.0 μm causes an increased number of scratches.

The polishing machine is not particularly limited, and, for example, a disk polishing machine or a linear polishing machine may be used. For example, common polishing machines having a holder for holding a work material and a polishing table for attaching a polishing pad that is connected to a variable frequency motor may be used. An example is a polishing machine EP0111, manufactured by Ebara Corporation.

In particular in the polishing method by using a polishing pad of the third embodiment allowing optical detection of polishing end point, the polishing end point is managed by irradiating a light at a wavelength of 190 to 3,500 nm via the polishing pad onto the polishing plane of the work material and detecting the change in reflectance while polishing the work material's polishing plane by sliding the polishing pad relatively to the work material as described above.

For use of the polishing pad of the third embodiment, the polishing machine should have a device for irradiation of a laser beam and detection of the reflected beam that is connected to the polishing table for attaching the polishing pad, as in the MIRRA polishing machine manufactured by Applied Materials U.S. The polishing condition is not particularly limited, but is preferably optimized according to the polishing work material. For accurate polishing, the polishing end point is managed in the polishing machine by detecting exposure of the silicon nitride film in the shallow trench isolation step or exposure of the barrier film in the damascene method while measuring reflection of the light irradiated onto the wafer surface. The program for managing the progress of polishing is installed previously to the polishing machine.

For fixing the polishing pad according to the present invention to the polishing table of polishing machine, an adhesive such as double-faced adhesive tape may be used on the face of the pad opposite to the polishing plane. Alternatively, it may be attached with a low-elastic modulus subpad, for example, of polyurethane foam.

Typically to polish a work material by pressing its polishing plane to a polishing pad and sliding the polishing pad relatively to the work material, at least one of the work material and the polishing table is moved. Polishing may be performed by rotation or reciprocating motion of the holder, instead of rotation of the polishing table. Other examples include polishing methods of revolving polishing tables planetary and moving a belt-shaped polishing pad linearly in the longitudinal direction, and the like. The holder may be fixed, rotated, or moved reciprocally. The polishing method is not particularly limited, if it can move the polishing pad and the work material relatively to each other, but should be selected properly according to the work material's polishing plane and the polishing machine used.

The polishing condition is not particularly limited, and preferably optimized according to the work material. For example, the rotational velocity of the polishing table is preferably lower at 200 rpm or less so that the work material will not be spun off, and the pressure applied to the work material is preferably lower, for example at about 50 kPa or less, when the work material's polishing plane is copper, for prevention of generation of scratches during polishing. In addition, the pressure is preferably 20 kPa or less when a work material having a low-dielectric constant interlayer insulating film is used.

Polishing slurry is supplied continuously, for example, by a pump between the polishing pad and the work material's polishing plane during polishing. The feed rate is not limited, but the surface of the polishing pad is preferably covered always with the polishing slurry. The pad and the exposed organic fiber

degenerated by polishing are regenerated and preserved by dressing. The work material after polishing is preferably washed thoroughly with running water and dried after the water drops on the polishing plane are removed, for example, by using a spin dryer.

Hereinafter, as an embodiment of the polishing method according to the present invention, a polishing method when the work material's polishing plane is a laminate film consisting of a barrier conductor layer and additionally a metal layer such as of copper that is formed on an insulation layer that has wiring and trenches formed thereon will be described, along with the steps of forming the wiring on semiconductor device.

For Example, the metal layer is a layer containing a metal as the principal material such as a layer of a metal selected from the group consisting of copper, copper alloys, copper oxide, and copper alloy oxides (hereinafter, referred to as "copper and the compounds thereof") or a metal such as tungsten, tungsten alloys, silver, or gold; and a layer containing copper as the principal component such as a layer of copper or the compound thereof is preferable.

The barrier conductor layer (hereinafter, referred to as "barrier layer") coated by the metal layer is preferably a barrier layer against copper and the compounds thereof, in particular against copper and copper alloys among the metals above. The barrier layer is formed for prevention of diffusion of the metal layer into the insulation film and improvement in adhesion between the insulation film and the metal layer. Examples of the compositions for the conductive layer include tantalum, titanium, tungsten, the compounds thereof such as nitrides, oxides and alloys,

and the like.

Examples of the insulation films include interlayer insulating films such as silicon film and organic polymer film. Examples of the silicon films include silicon dioxide, fluorosilicate glasses, organosilicate glasses obtained by using trimethylsilane or dimethoxydimethylsilane as the starting material, silicon oxynitride, silica-based films such as hydrogenated silsesquioxane, silicon carbide, and silicon nitride. In addition, examples of the organic polymer films include wholly aromatic low-dielectric constant interlayer insulating films. In particular, the interlayer insulating film preferably has a dielectric constant of 2.7 or less.

First, an interlayer insulating film, for example, of silicon dioxide is laminated on a silicon substrate. The interlayer insulating film surface is then converted to an interlayer insulating film having a surface irregularity by forming a certain pattern by concave areas (substrate exposed areas) by any one of known means such as resist layer formation or etching. A barrier layer, for example, of tantalum is deposited, for example, by vapor deposition or CVD along the surface irregularity on the interlayer insulating film. Further, a metal layer, for example, of copper covering the barrier layer is formed for example by vapor deposition, plating, or CVD, filling the concave areas in the barrier layer.

Then, the metal layer on the surface of substrate is polished by CMP by using the polishing pad according to the present invention while supplying polishing slurry (first polishing step). Thus, the barrier layer of the convex area on the substrate is exposed on the surface, giving a desired wiring pattern that still retains

the metal film in the concave areas. Part of the barrier layer of the convex area may be polished together with the metal layer during the polishing. In the second polishing step, at least the exposed barrier layer and the metal layer in concave areas are polished by CMP, by using a polishing slurry allowing polishing of the metal, barrier and interlayer insulating layers. The polishing is terminated when a desired pattern is obtained in which the interlayer insulating film under the protruding barrier layer is exposed entirely, the metal layer for wiring layer is left in the concave areas, and the cross sectional area of the barrier layer is exposed at the boundary of convex area and concave area. The polishing pad according to the present invention is used at least in the second polishing step, but preferably used also in the first polishing step, as shown in this embodiment.

For ensuring the superiority in flatness after polishing, it may be over-polished (e.g., if a desired pattern is obtained within 100 seconds in the second polishing step, polishing additionally for 50 seconds is called 50% over-polishing) to a depth including part of the interlayer insulating film of convex area.

The polishing pad and the polishing method using the same according to the present invention can be applied, not only to polishing of films containing mainly a metal such as Cu, Ta, TaN, or Al filling the composite opening of the insulation layer described above, but also to polishing of inorganic insulation films such as silicon oxide film, glass, and silicon nitride formed on a certain wiring board, films mainly containing polysilicon, optical glasses such as photomask, lens, and prism, inorganic

conductive films such as ITO, end faces of optical integrated circuit, optical switching device, optical waveguide, and optical fiber made of a glassy or crystalline material, optical single crystals such as scintillator, single crystals for solid state laser, sapphire substrates for blue laser LED, semiconductor single crystals of SiC, GaP, GaAs, and the like, glass or aluminum substrates for magnetism disk, magnetic head, and the like.

EXAMPLES

Hereinafter, the present invention will be described in detail with reference to Examples, but it should be understood that the present invention is not restricted by these Examples.

(Example 1)

An organic fiber, poly-p-phenylene terephthalamide fiber (trade name "Kevlar", manufactured by DuPont, fiber diameter: 12.5 μm, fiber length: 3 mm) and a matrix composition, ABS resin pellet, were melt-blended and tabletized in an extruding molding machine. The content of the poly-p-phenylene terephthalamide fiber was adjusted to 10 wt %. The tablet obtained was dried in a large-sized dryer at 120°C for 5 hours, and then processed into a sheet-shaped molding of 1.2 mm in thickness and 1 m in width by using an extrusion-molding machine and a roll. Trenches having a cross section in the rectangular shape having a depth of 0.6 mm and a width of 2.0 mm were formed on the sheet in the grid pattern at a pitch of 15 mm, and then, the sheet was cut into a circular form. In addition, a double-sided adhesive tape was adhered to the face opposite to the face whereon the trenches were formed, and it was used as a polishing pad.

(Example 2)

A polishing pad was prepared in a similar manner to Example 1, except that a mixture of polyethylene, polypropylene, and styrene elastomers at a ratio of 50:50:100 by weight is used as the matrix composition.

(Example 3)

A polishing pad was prepared in a similar manner to Example 1, except that polypropylene was used as the matrix composition.

(Comparative Example 1)

A polishing pad was prepared in a similar manner to Example 1, except that no organic fiber was used.

(Comparative Example 2)

A polyurethane foam polishing pad was prepared.

The pad was attached to the polishing table of a polishing machine and surface-roughened by using a dresser with #160 diamond whetstone for 30 minutes.

(Preparation of polishing slurry)

An abrasive-free polishing slurry (trade name: HS-C430 slurry, manufactured by Hitachi Chemical Co., Ltd.) and the same polishing slurry with colloidal silica as the abrasive having an average secondary particle diameter of 35 nm at a concentration of 0.37 wt % were used as polishing slurries for copper. Both polishing slurries were blended with a hydrogen peroxide solution at a rate, polishing slurry: hydrogen peroxide solution, of 7:3 when using.

(Polishing of substrate)

By using the polishing pads prepared in Examples and Comparative Examples and the polishing slurry prepared above,

silicon wafer substrates with and without wiring were polished as follows, and the polishing speed, the polishing scratch, and the dishing, an indicator of flatness, were determined.

The wafer was placed on a holder with an adhesive pad for attaching wafer in a polishing machine. Each of the polishing pads prepared in Examples and Comparative Examples was adhered to the polishing table of the polishing machine and the holder having a work material with its polishing plane facing downward was attached on it in the polishing machine. The work material's polishing plane was polished under an applied load of 4×10^4 Pa, while supplying the polishing slurry at a flow rate of 150 cc/min and rotating the polishing table and the wafer at a frequency of 38 rpm; and the polishing was evaluated. Results are summarized in Table 1.

(Evaluation of polishing speed)

A silicon wafer substrate (diameter: 13 cm) having a silicon dioxide film layer without wiring on which a copper film of 1 μm in thickness is formed was polished for 2 minutes. The thicknesses of the copper film before and after polishing were determined by measuring the sheet resistivity by using a resistivity meter RT-7 manufactured by Napson Corporation and calculating the film thickness from the resistivity, and the difference between the film thicknesses before and after CMP was calculated. Results are summarized in Table 1.

(Evaluation of polishing scratch)

The number of the scratches on the wafer used for evaluation of polishing speed was counted by visual observation. Results are also summarized in Table 1.

○: Less than five scratches on the work material's polishing plane after polishing

×: Five or more scratches on the work material's polishing plane after polishing

(Dishing amount)

A silicon substrate (diameter: 13 cm) having a surface shape in the striped pattern consisting of wiring metal (copper) areas of 100 μm in width and insulation film (silicon dioxide) areas of 100 μm in width that are formed alternately was prepared as a work material, by forming a silicon dioxide film having a thickness of 300 nm on a silicon wafer, forming trenches having a depth of 0.5 μm on the silicon dioxide film at a wiring density of 50%, forming a tantalum nitride film having a thickness of 50 nm as a barrier layer by a known sputtering method, and forming a copper film of 1.0 μm in thickness similarly by sputtering and embedding it by a known heat treatment.

The work material was subjected to two-step polishing, polishing of copper film and of barrier layer, and the decrease in the amount of film in wiring metal area from that in the insulation film area was determined from the surface shape in the stripe-patterned area, as determined by using a stylus profilometer (Dektat3030, manufactured by Veeco/Sloan). Results are also summarized in Table 1. "No measurement possible" in the Table, means that the substrate could not be polished at low polishing speed or that there were too many polishing scratches prohibiting measurement.

Polishing pads prepared in Example 1 and Comparative Example 1 have the same matrix resin and differ from each other in whether

the substrate contains fiber. The polishing pad of Example 1 according to the present invention is resistant to generation of scratches and thus superior to the pad of Comparative Example 1 containing no organic fiber. The pad of Comparative Example 1 resulted in a greater number of polishing scratches, which prohibited dishing measurement. In the Example, use of an abrasive-free polishing slurry almost prohibited polishing, and thus, the polishing mechanism in the Example is obviously different from that in Comparative Example 1 or 2, which is higher in polishing speed.

Table 1

Pad	Polishing slurry	Polishing speed (Å/min)	Scratches	Dishing (Å)
Example 1	Abrasive-free polishing slurry	50	○	No measurement possible
	Abrasive-containing polishing slurry	1000	○	300
Example 2	Abrasive-free polishing slurry	70	○	No measurement possible
	Abrasive-containing polishing slurry	1000	○	300
Example 3	Abrasive-free polishing slurry	40	○	No measurement possible
	Abrasive-containing polishing slurry	800	○	300
Comparative Example 1	Abrasive-free polishing slurry	1000	×	No measurement possible
	Abrasive-containing polishing slurry	1500	×	No measurement possible
Comparative Example 2	Abrasive-free polishing slurry	2200	○	500
	Abrasive-containing polishing slurry	2500	○	1100

Then, a polishing test was performed in a similar manner to above, except that an abrasive-containing polishing slurry, which was higher in polishing speed from the results above, was used and a processing load of 2×10^4 Pa was applied. Results are summarized in Table 2. As apparent from Table 2, there was almost no difference between the polishing speeds in Examples and those under the polishing conditions above, indicating that it was possible to polish even under a low load, i.e., under a low friction

force. On the other hand in Comparative Examples, the polishing speed decreased drastically under low load, for example, under this condition.

Table 2

Pad	Polishing speed (Å/min)	Scratches	Dishing (Å)
Example1	700	○	300
Example2	700	○	300
Example3	700	○	300
Comparative Example 1	400	×	No measurement possible
Comparative Example 2	100	○	600

The results above indicate that use of the polishing pad according to the present invention allows improvement in flatness while reducing the load applied to the insulation layer during CMP.

Hereinafter, the polishing pad according to the present invention suitable for use in the polishing step of irradiating light via a polishing pad onto the semiconductor wafer surface, detecting the change in the reflectance, and managing the polishing end point will be described with reference to Examples, but the present invention is not limited to these Examples.

For preparation of polishing pads, prepared were the following plate materials 1 to 3.

[Plate material 1]

An organic fiber, poly-p-phenylene terephthalamide fiber ("Kevlar", manufactured by DuPont, fiber diameter: 12.5 μm, fiber

length: 3 mm), and a matrix resin, AS resin pellet (trade name: Litac A-100PC, manufactured by Nippon A&L Inc.), were melt-blended in an extruding molding machine and then tabletized. The poly-p-phenylene terephthalamide fiber was adjusted to a content of 5 wt %. The tablet was dried in a large-sized dryer at 120°C for 5 hours, and a sheet-shaped molding of 1.2 mm in thickness and 1 m in width was prepared by using an extrusion-molding machine and a roll.

[Plate material 2]

The AS resin pellet (ditto) was melt-blended in an extruding molding machine and tabletized. The tablet was dried in a large-sized dryer at 120°C for 5 hours, and a sheet-shaped molding of 1.2 mm in thickness and 1 m in width was prepared by using an extrusion-molding machine and a roll. The plate material contains no organic fiber.

[Plate material 3]

A chopped para-aramide fiber ("Kevlar", manufactured by DuPont, fiber diameter: 12.5 μm, fiber length: 5 mm), a para-aramide fiber pulp ("Kevlar", manufactured by DuPont, fiber diameter: 1 μm, fiber length: 1 mm), and a chopped meta-aramide fiber ("Conex", manufactured by Teijin Ltd., fiber diameter: 25 μm, fiber length: 6 mm, softening temperature: 280°C) were blended; an aqueous solution of 20 wt % of water-soluble epoxy resin binder (trade name: "V Coat", manufactured by Dainippon Ink and Chemicals, Inc., glass transition temperature: 110°C) was sprayed thereon and the mixture was dried by heating (150°C, 3 min); and the mixture was heat-compressed between a pair of heated rolls (temperature: 300°C, linear pressure: 196 kN/m), to give a nonwoven fabric wherein the

chopped meta-aramide fiber was fused thermally to the chopped para-aramide fiber. The basis weight was 70 g/m^2, and the ratio of chopped para-aramide fiber/para-aramide fiber pulp/chopped meta-aramide fiber/epoxy resin binder was 58/17/8/17 by weight.

A varnish containing bisphenol A epoxy resin (trade name: "EP-828SK", manufactured by Yuka Shell Epoxy K.K.), a curing agent dicyandiamide and an accelerator 2-ethyl-4-methylimidazole was prepared. For preparation of the varnish, 20 parts by weight of the curing agent, 0.1 parts by weight of the accelerator, and 40 parts by weight of a solvent methylethylketone were used with respect to 100 parts by weight of the bisphenol A epoxy resin.

The aramide fiber nonwoven fabric described above was impregnated with the varnish, and the mixture was dried under heat (170°C, 5 min), to give a prepreg. The amount of the resin added was adjusted in such a manner that the prepreg after molding with heating and pressure had a thickness of 0.08 mm. The content of the aramide fiber nonwoven fabric was 60 wt %.

A laminated plate having a thickness of 1.0 mm was obtained by piling twelve prepreg layers together with two release films (polypropylene film of 50 μm in thickness) at both ends, holding the pile between two mirror-surfaced stainless steel plates, placing multiple sets thereof in a hot press via two thickness cushion material of 10 mm in thickness made of multiple Kraft paper layers, and molding them with heating and pressure (temperature: 170°C, pressure: 300 kPa, period: 120 min).

(Example 3)

The plate material 1 was cut into a circular disc of φ500 mm; trenches are formed on the surface thereof so that a polishing

slurry supplied during polishing flows under the jig holding the wafer to below the wafer (in a grid pattern, trench width: 2 mm, trench pitch: 15 mm, trench depth: 0.6 mm); and a double-sided adhesive tape was adhered to the opposite face, to give a polishing pad.

(Example 4)

The plate material 1 was cut into rectangular disk-shaped small pieces of 56 mm in length and 19 mm in width with rounded edges (curvature radius: 1.0 mm). Then, the plate material 3 was cut into a circular disc of φ500 mm in a similar manner to Example 3, and trenches were formed on the surface thereof. A hole in the rectangular disk shape of 56 mm in length and 19 mm in width with rounded edges similar to the edges described above was formed at a position halfway from the center of the circular disc to the circumference in the radial direction, in the manner that the longitudinal direction of the hole represents the radial direction. The small piece in the rectangular disk shape described above of plate material 1 was inserted to the circular disc hole as a window for transmitting light for optical detection. Finally, a double-sided adhesive tape was adhered to the face opposite to the face where the trenches were formed, to give a polishing pad.

(Traditional Example 1)

A commercially available polishing pad of a polyurethane foam resin, having a light transmission window of a transparent resin plate for optical detection in a rectangular disk shape of 56 mm in length and 19 mm in width with rounded edges, was made available. ("IC-1000/Suba-400" prepared by Rodel Inc., thickness: 1.2 mm)

(Comparative Example 3)

A polishing pad was prepared by processing the plate material 2 in a similar manner to Example 3.

(Reference Example 1)

A polishing pad was prepared by processing the plate material 3 in a similar manner to Example 3. The polishing pad does not have a window, different from that in Example 4.

The light transmittance of the polishing pads obtained in the Examples, the Traditional Example, the Reference Example and the Comparative Example was determined. The measurement was performed at the window if the polishing pad has a light transmission window, and at the plate material of the polishing pad if not. The light transmittance was determined at a measurement wavelength of 670 nm by using a spectrophotometer UV-2200 manufactured by Shimadzu Corp. The measured value was converted to a transmittance of a plate of 1 mm in thickness, by using Lambert-Beer's law.

The polishing machine used was MIRRA manufactured by Applied Materials U.S. and each of the polishing pads was adhered and fixed to its polishing table of φ500 mm. As for polishing pads having a light transmission window for optical detection, the window of the polishing pad was adjusted to the window of the polishing table of polishing machine. Each polishing pad, after adhered to the polishing table, was subjected to dressing at 9LB for 15 minutes, as a diamond dresser manufactured by Asahi Diamond Industrial Co., Ltd. (whetstone: #170, acryl coated) is fit to the pad conditioner mechanism in the polishing machine. Observation of the surface state of each polishing pad revealed that the fiber is exposed on the surface of the polishing pads of Example 3 and Reference

Example 1 (exposure length: approximately 500 μm). The fiber was exposed (exposure length: approximately 500 μm) similarly on the window as well as on the entire surface of the polishing pad of Example 4. Exposure of the fiber was not observed on the polishing pads of Traditional Example 1 and Comparative Example 3.

The structure, the surface state and the light transmittance of the polishing pads of the Examples, the Traditional Example, the Reference Example and the Comparative Example are summarized in Table 3.

Table 3

	Structure	Window	Light trans -mittance (%)	Surface state
Example 3	AS resin plate with aramide fiber	not have	49.1	Fiber exposure
Example 4	epoxy resin plate with aramide fiber	have (Plate material 1)	49.1	Fiber exposure
Traditional Example 1	polyurethane foam resin plate (two-layers structure)	have	67.2	No fiber exposure
Comparative Example 3	AS resin plate	not have	94.5	No fiber exposure
Reference Example 1	epoxy resin plate with aramide fiber	not have	3.6	Fiber exposure

Silicon wafers (insulation film blanket wafer and TEG wafer) were polished as follows by each of the polishing pads of the Examples, Traditional Example, Reference Example and Comparative Example placed in a polishing machine as described above, and the CMP

polishing slurry, and the characteristics were evaluated from the following viewpoints. The evaluation results are summarized in Table 4.

(Evaluation of the number of polishing scratches)

A blanket wafer having a silicon oxide film of 1 μm in thickness formed on a φ200 mm silicon wafer by the TEOS-plasma CVD method was placed in a polishing machine. Then, the wafer is held by the head-unit and the silicon oxide film side was brought into contact with the polishing pad on the polishing table. The silicon oxide film on wafer was polished for 1 minute under a polishing pressure applied on the wafer surface during polishing set to 21 kPa (3 PSI) while supplying a mixture of a cerium oxide-based polishing slurry (HS-8005, manufactured by Hitachi Chemical Co., Ltd.) at a feed rate 40 mL /min and an additive (HS-8102GP, manufactured by Hitachi Chemical Co., Ltd.) at a feed rate of 160 mL /min by dropping onto the polishing table and rotating the polishing table at 100 rpm and the head at 90 rpm. The silicon wafer after polishing was washed thoroughly with purified water and dried, and then, the entire surface of the wafer was observed in dark field under a microscope and the number of the polishing scratches was counted.

(Evaluation of polishing speed)

The thickness of the silicon oxide film on each blanket wafer after evaluation of the number of polishing scratches was determined by using a light-interference thickness analyzer, and an average polishing speed was determined from the difference from the thickness of silicon oxide film determined before polishing.

(Evaluation of uniformity)

The polishing speeds of the silicon oxide film at 45 point at an interval of 8 mm from the position at 5 mm separated from terminal on two diameters orthogonal to each other on each blanket wafer face were determined in a similar manner to the measurement of polishing speed, and the variations (1δ/average polishing speed ×100) in polishing speed was calculated from the standard deviation (1δ).

(Evaluation of possibility of end point management)

A pattern of lines having a width and a pitch respectively of 25 to 2,000 μm was formed with a silicon nitride film having a thickness of 100 nm on a φ200 mm silicon wafer; the Si exposed area was etched to a depth of 350 nm; and a silicon oxide film was formed on the wafer by the TEOS-plasma CVD method to a thickness of 600 nm, to give a TEG wafer having an irregularity of 450 nm on the surface. While polishing the wafer under the same condition as the blanket wafer described above, it was judged whether it is possible to detect exposure of the silicon nitride film, by using the ISRM laser-beam end point-managing system attached to the polishing machine (MIRRA, manufactured by Applied Material Technologies) used for evaluation.

(Evaluation of flatness)

After polishing and detecting the exposure of silicon nitride film by the end point management system described above, the difference in surface level between the line (width 100 μm) of the silicon nitride film on the TEG wafer after and the line of the neighboring silicon oxide film (width 300 μm) was determined by using a stylus profilometer Dektak3030 (manufactured by SLOAN).

Table 4

	Polishing speed (nm/min)	Uniformity (%)	Scratch (number /wafer)	End point management	Flatness (mm)
Example 3	280	3	3	possible	20
Example 4	290	5	5	possible	25
Traditional Example 1	180	5	30	possible	20
Comparative Example 3	210	12	55	possible	20
Reference Example 1	310	5	5	Not possible	—

The results of examples 3 and 4 in Table 4 show that use of the polishing pad according to the invention allows management of the end point by optical detection, and comparison with the results in Traditional Example 1 and Comparative Example 3 shows that it is possible to suppress generation of polishing scratches by the action of the organic fiber. It was also confirmed that the polishing speed was higher and the uniformity was also sufficiently high. The polishing pad of Reference Example 1 did not show a sufficiently distinctive change in reflectance for allowing detection of the end point by light irradiation during polishing of the TEG wafer evaluated. It corresponds to the fact that the polishing pad of Reference Example 1 showed low light transmittance in the earlier experiment.

Hereinafter, Examples concerning the maximum exposure fiber length will be given.

(Example 5)

A nonwoven fabric having a basis weight of 70 g/m²

("EPM-4070TE", manufactured by Japan Vilene Co., Ltd.) made of a polyester fiber having a fiber diameter of 12.5 μm and a fiber length of 5 mm was impregnated with the following varnish, and the mixture was dried at 170°C for 5 minutes, to give a prepreg.

The varnish was prepared by adding 20 parts by weight of a curing agent dicyandiamide and 0.1 parts by weight of an accelerator 2-ethyl-4-methylimidazole to 100 parts by weight of a bisphenol A epoxy resin and dissolving the mixture in 40 parts by weight of methylethylketone.

Twenty prepregs were piled between a pair of release films (polypropylene, thickness: 50 μm), and the pile was held between a pair of mirror-surface plates. It was molded via two cushion papers having a thickness of 10 mm in a hot press with heating and pressure. The molding condition was 175°C and 400 kPa for 120 minutes. As a result, a laminated plate having a thickness 1.5 mm was obtained. The fiber content in the entire laminated plate was 50 wt %. The plate was cut into a circular form; the surface was roughened by using #70 diamond whetstone; and then trenches are formed thereon, to give a polishing pad. Trenches of 2 mm in width and 0.6 mm in depth were formed in a grid pattern with a pitch of 15 mm.

(Example 6)

A laminated plate of 1.5 mm in thickness was prepared in a similar manner to Example 5, except that ten prepregs shown in Example 5 and ten non-resin-impregnated polyester nonwoven fabrics were laminated alternately. The fiber content in the entire laminated plate was 70 wt %. Then, the surface was roughened and trenches are formed in a similar manner to Example 5, to give a

polishing pad.

(Example 7)

A polishing pad was prepared in a similar manner to Example 5, except that a polyester woven fabric having a basis weight of 130 g/m^3 ("BKE poplin", manufactured by Asahi Kasei Corp., fiber diameter: 9 μm) was used as the fiber. In this Example, the fiber content in the entire laminated plate was 50 wt %.

(Example 8)

An organic fiber, polyester fiber having a diameter of 12.5 μm and a length of 3 mm (manufactured by Japan Vilene Co., Ltd.), and a matrix resin, ABS resin pellet, were melt blended in an extruding molding machine and tabletized. The fiber content therein was adjusted to 10 wt %. The tablet was dried in a large-sized dryer at 120°C for 5 hours, and was converted by using an extrusion-molding machine and a roll into a sheet-shaped molding having a thickness of 1.2 mm and a width of 1 m. Trenches having a rectangular cross section of 0.6 mm in depth and 2.0 mm in width were formed thereon in a grid pattern with a pitch of 15 mm, and the molding was cut into a circular plate. Then, a double-sided adhesive tape was adhered to the face opposite to the face whereon the trenches are formed, and then, the surface was roughened by using #70 diamond whetstone, to give a polishing pad.

(Reference Example 2)

A polishing pad was prepared in a similar manner to Example 5, except that a nonwoven fabric having a basis weight of 70 g/m^2 was prepared by spraying an aqueous 20 wt % solution of a water-soluble epoxy resin binder (trade name: "V Coat", manufactured by Dainippon Ink and Chemicals, Inc.) on a blend of

a chopped para-aramide fiber ("Technola", manufactured by Teijin Ltd., fiber diameter: 12.5 μm, fiber length: 5 mm) and a chopped meta-para-aramide fiber ("Conex", manufactured by Teijin Ltd., fiber diameter: 25 μm, fiber length: 6 mm) and drying the mixture at 150°C for 3 minutes under heat, and the nonwoven fabric was heat compressed between heat rolls at 300°C, under an applied linear pressure of 196 kN/m. In addition, the surface was roughened by using #150 diamond whetstone. In the Reference Example, the fiber content in the entire laminated plate was 50 wt %.

(Comparative Example 4)

An ABS (acrylonitrile-butadiene rubber-styrene copolymer) plate having a thickness of 1.5 mm was cut into a circular form, and trenches of 2 mm in width and 0.6 mm in depth were formed on the surface in a grid pattern with a pitch of 15 mm. Then, the surface was roughened by using #70 diamond whetstone to give a polishing pad.

(Reference Example 3)

A polishing pad was prepared in a similar manner to Example 8, except that the surface was roughened by using #70 diamond whetstone.

(Observation of surface)

The pad surface at any five points was observed under an SEM (scanning electron microscope) at magnifications of 100 and 200 times, and the maximum length of exposed fiber was determined.

(Polishing slurry)

A CMP slurry was prepared as the polishing slurry by the following method:

Two kg of cerium carbonate hydrate was place in a platinum

container and sintered at 800°C for 2 hours in air, and 1 kg of the cerium oxide powder thus obtained was pulverized in a jet mill while it is dry. Twenty-three grams of an aqueous ammonium polyacrylate salt solution (40 wt %) and 8,977 g of deionized water were added thereto, and the mixture was ultrasonicated for 10 minutes while agitated. The slurry obtained was filtered through a 1-micron filter, and deionized water was added thereto, to give a 5 wt % slurry. The pH of the slurry was 8.3. After dilution to a suitable concentration, the slurry particles were analyzed by using a laser diffraction particle size distribution analyzer, and as a result, D99% of particle diameter was 0.99 μm.

(Polishing method and evaluation of polishing characteristics)

Prepared were a blanket wafer having a silicon oxide film of 2 μm in thickness formed on a φ127 mm silicon wafer by the TEOS-plasma CVD method, and a test wafer carrying trenches having a square convex area formed on a φ200 mm Si substrate and additionally a Si_3N_4 film and a silicon oxide film having a thickness of 600 μm formed by the TEOS-plasma CVD method thereon. The trench had a depth of 0.35 μm; the region where the density of the convex area was 60%, and the trench width is 500 μm was used.

The wafer was placed on the holder of polishing machine with the adhesive pad for attaching to a wafer substrate; the polishing pad prepared was adhered to the φ380 mm polishing table; the holder was placed on the polishing table with the insulation film side facing downward; and the processing load was set to 29 kPa (300 gf/cm^2). The insulation film was polished by rotating the polishing table and the wafer at 38 rpm for 2 minutes while supplying the cerium oxide polishing slurry at a rate of 150 cc/min by dropping

on the polishing table. The wafer after polishing was washed thoroughly with purified water and then dried. The difference between the film thicknesses before and after polishing was measured by using a light-interference film thickness analyzer and the polishing speed was calculated. As for polishing scratch, the wafer surface after polishing was observed in dark field under a microscope and the number of the scratches remaining on the wafer surface due to polishing was counted.

Alternatively as for evaluation of flatness, the wafer was polished to a depth equivalent to the difference, 1 μm, in the levels of the convex area and concave area on TEG wafer, and the final difference in level before exposure of the convex area Si_3N_4 film was determined. The dishing in the trench area on the TEG wafer was determined by using a stylus profilometer.

Table 5 shows the polishing characteristics obtained in the Examples, Reference Example and Comparative Example. In Examples 5, 6, 7 and 8 where the polishing pad contains the polyester fiber according to the invention was used, it is possible to reduce the length of the exposed fiber easily and the polishing pad is superior in flatness and the wafer surface has fewer polishing scratches, compared to in Reference Example 2 wherein the pad contains a high-rigidity aramide fiber. In addition, as apparent from comparison between Examples 5, 6, 7 and 8 and Comparative Example 4 containing no fiber, the polishing speed was improved and the polishing scratches were fewer as well.

Table 5

	Maximum exposure fiber length (μm)	Polishing speed (nm/min)	Scratch (number /wafer)	Flatness	Dishing (nm)
Example5	10	210	0	20	25
Example6	10	240	0	20	28
Example7	10	240	0	20	29
Example8	10	220	10	30	25
Reference Example 2	50	190	40	20	40
Comparative Example 4	0	10	250	No measurement possible	No measurement possible
Reference Example 3	150	350	0	50	50

As apparent from Table 5, it is possible to improve the flatness and the dishing-resistivity in the trench area without generating polishing scratches by using a polishing pad having a maximum exposure fiber length of 0.1 mm or less and to streamline semiconductor forming processes including flattening of interlayer insulating film, BPSG film, and production of shallow trench isolation formation.

INDUSTRIAL APPLICABILITY

If CMP is performed by using the polishing pad according to the present invention or the polishing pad prepared by the production method according to the present invention, it is possible to suppress generation of minute polishing scratch on the work material, because of the organic fiber exposed on the

work material-side surface of the polishing pad. Thus, it is possible to polish in superior flatness at low load. In addition, it is also possible to manage the polishing end point of the work material while suppressing generation of polishing scratches by using an optical detection system monitoring the polishing state of work material. These effects in combination enable improvement in the productivity and the yield of the polished work material.

Thus, for example, it is possible to polish substrates under a smaller load on the interlayer insulating film and give products superior in flatness in semiconductor device manufacturing processes and thus, the polishing pad according to the invention may be used easily in the next-generation dual damascene method.